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ABSTRACT

This paper advocates the deliberate and consistent use of educational simulations and games as one way of improving mathematics instruction. Dewey's philosophy to rationalize using simulations and games in mathematics classes is discussed. A drill and practice type of mathematical simulation game called Mathardy is illustrated. It is concluded that better teaching of mathematics through the use of educational simulations has serious potential to improve both students' attitudes toward mathematics and their actual achievement. (Contains 14 references.) (ASK)

The Use of Educational Simulation and Gaming To Improve Mathematics Teaching

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THE USE OF EDUCATIONAL SIMULATION AND GAMING TO IMPROVE MATHEMATICS TEACHING

Introduction

In the present article, the authors are advocating the deliberate and consistent use of educational simulations and games as one way of improving mathematics instruction. How is educational gaming likely to improve instruction? First of all, children in early grades learn mathematics more effectively when they use physical objects in their lessons. As the former Secretary of Education, William Bennett (1986, p. 29), points out:

> Numerous studies of mathematics achievement at different grade and ability levels show that children benefit when real objects are used as aids in learning mathematics. Teachers call these objects "manipulatives." Objects that students can look at and hold are particularly important in the early stages of learning a math concept because they help the student understand by visualizing. Students can tie later work to these concrete activities.
>
> The type or design of the objects used is not particularly important; they can be blocks, marbles, poker chips, cardboard cutouts -- almost anything. Students do as well with inexpensive or homemade materials as with costly, commercial versions.
>
> The cognitive development of children and their ability to understand ordinarily move from the concrete to the

abstract. Learning from real objects takes advantage of this fact and provides a firm foundation for the later development of skills and concepts.

Based upon our own experiences with educational gaming, the authors contend that the same benefits that derive for younger students can be provided to older students who are learning more complex math subjects, such as algebra, geometry, trigonometry, or calculus. To site anecdotal evidence, one of the authors has developed and successfully implemented over half-a-dozen educational simulations during the past ten years (Lemire, 1976; 1983; 1985; 1986; Lemire & Cox, 1987; Lemire & Mitchell, 1989) These educational games have been found to reinforce other kinds of learning, as well as to establish an "anticipatory set" for further learning in all kinds of educational settings from elementary school to college level. In the study of the effectiveness of educational gaming as compared to traditional methods of instruction, Lemire has consistently observed results which indicate that educational gaming is at least as effective, if not superior, to traditional methods.

Empirically validated research also seems to support the use of educational simulations and gaming as an effective instructional methodology. For example, reviewing the results of twenty-two studies, Pierfy (1977) found that simulations were more effective than conventional instructional methods in fostering student interest and positive attitudes toward subject matter. The potential of educational gaming is even greater if

one considers that educational simulations and gaming are multimodal instruction, that is, they utilize visual, auditory, and kinesthetic-tactile learning modalities.

Heitzmann (1974, pp. 20-21), summarizes the generalizations suggested to the classroom teacher regarding educational simulations and gaming:

(1) The interest in and expansion of simulations and games is extensive. Teachers can take advantage of interest by planning their instruction accordingly.

(2) Play is important if not vital to proper social, emotional, and intellectual development. Simulations can provide opportunities for students to "play" in structured yet open ways.

(3) The psychological atmosphere of the classroom is important to successful instruction. Educational games provide an opportunity for learner-centered instruction in a flexible leadership style for the teacher.

(4) Many commercial simulations exist in all subject areas. In addition, teachers can design their own educational games to fit their students' special situations.

(5) Regardless of the type of simulations used, teachers must be knowledgeable about the game and be aware of procedures to follow and avoid to maximize learning.

(6) Students are highly motivated by educational simulations and enjoy playing them.

(7) Simulations have been shown to be able to teach facts and other intellectual skills as well as alter the attitudes and opinions of participates.

The authors believe that the quality of instruction is intimately related to the structure of teaching. The tendency of teachers to rely heavily on lectures is highly regrettable. For many students lecturing is ineffective and offensive. Many educators believe that there is nothing that a talker can lecture on that cannot be printed so that students can read the material at their leisure. It is clear that to improve instruction, lecturing needs to be supplemented with activity-based teaching methods that have been shown to have a lasting impact on student learning outcomes.

John Dewey and Experiential Education

John Dewey, the most influential of American philosophers, was a thoroughgoing pragmatist and experimentalist. He believed that the true value of any learning was its usefulness to the individual and to society in practical, real life situations. In Experience and Education (1938, 73), Dewey stated that "Anything which can be called a study ... must be derived from materials which at the outset fall within the scope of ordinary life-experiences." His leading interpreter, William Heard Kilpatrick, underscored this practical and experiential thrust when he said that "Every subject should justify itself because it is useful to the student, and it should be taught for no other reason." (Tennenbaum, p. 103).

This does not mean that mathematics or any other subject is for the student only or for the student just as he or she is today. Dewey calls for the student to learn in the context of life experiences so that she or he will see, first of all the enjoyment and the relevance of the subject and then see more later, as experience unfolds and expands.

Experiential teaching is twofold. "It is part of the educator's responsibility," says Dewey (1938, p. 79), "to see equally to two things: First, that the problem grows of experience, and within the range of capacity of the student; Second, it arouses in the learner an active quest for information and the production of new ideas." Immediate enjoyable experiences can and will lead on to more complex and abstract levels of learning.

Kilpatrick, who wrote his doctoral dissertation under Dewey on the subject of the great European educator, Friedreich Froebel, has this to say in favor of a particular type of experiential education (Tennenbaum, 1951, p. 105):

> At least until the sixth grade, children will learn more and better mathematics in the normal course of living, while playing games, while making costumes for a play, while doing shopwork, while calculating the cost of a luncheon, while following recipes in cooking, while reckoning the cost of a proposed trip, etc.

Kilpatrick's belief is a restatement of the great principle of educative play, for which Froebel, the founder of the

kindergarten movement, was famous. But Froebel intended his educational reforms, based upon respect for the experiences of the learner and on learning-by-doing in a social setting, to apply to all levels of schooling. Dewey himself put this very clearly in The School and Society (Dewey, 1915, pp. 118-119):

> Play is not to be identified with anything which the child externally does. It rather designates his mental attitude in its entirety and is its unity. It is the free play, the interplay, of all the child's powers, thoughts, and physical movements, in embodying, in a satisfying form, his own images and interests.

Problem solving and educative play, simulation and gaming, hands-on activities -- all are involved in experiential education. Activities are keys to the present dilemma of developing an arithmetically and mathematically literate population. The old emphasis on "mind training" which was really a form of mental gymnastics, is, in Kilpatrick's words (Tennenbaum, 1951, p. 105), "an outworn discarded theory." The contemporary, changing scene, demands citizens who can think on their feet and tackle problems with confidence, agility, and zest.

"Mathardy": A Mathematical Simulation Game

Drill and practice is an essential element of most math programs. Mathardy a lower-level simulation that helps students with this tedious aspect of math instruction. Unfortunately, the structure of drill and practice sessions may be inherently

mundane because of the lack of creativity given to the instructional activities. Too often, drill and practice is synonymous with boring, uneventful, and tedious work sheets. The students are expected to work individually and complete what seems to be a never-ending inventory of math problems. Without motivation, either intrinsic or extrinsic, the acquisition of skills through drill and practice is severely impaired.

When drill and practice can be altered, for instance through an educational game or simulation, the internal motivation of students is given a boost and increased learning follows. For example consider "Mathardy," a game similar to the television game show, "Jeopardy." Mathardy (Carol, 1977) shrouds the drill and practice components within a cloak of friendly competition. Mathardy can be used at any grade level and with just about any subject matter. This game can be especially useful as a culminating activity, as a review session, or just for a fun learning activity.

A transparency, displayed on an overhead projector, acts as the game board (Figure 1). The board consists of five questions (rows) in five different categories (columns). Ideally, even though it requires more preparation, the math problems would be of increasing difficulty and therefore higher point values as they proceed down a column.

The answers on the overhead are covered by slips of papers which are simply pulled down to reveal the next question. An alternate method could be to conceal the answers by tape or

prepare a second transparency containing only answers. In any case, the teacher should have an answer sheet available so the student responses can be quickly evaluated.

Even though Mathardy can be played as a team game, it is most effective to have the students play individually, keeping their own scores. Officials such as a scorekeeper or judges may be assigned, but are not really necessary. To add to the congenial competition the winners may be offered some small prize such as a candy bar or small toy.

An initial student is chosen who then picks a category and point value for a question. The instructor reveals the chosen question and then watches the class carefully for the order of the first students to raise their hands. Before a hand is raised, the answer must be written and circled on a piece of paper; after the hand is raised the student can not alter the answer. It is imperative to allow enough time for all students to attempt each problem. When enough time has been given, the student who raised his or her hand first is asked for the answer. If that student gives an incorrect response, the student whose hand was up next is called upon. The procedure is repeated until a student gives a correct answer. This student is then awarded the privilege of selecting the next category and an unanswered question.

The full point value of the question is awarded to the first student who gives the correct answer; an incorrect value results in the point value being subtracted from the student's score. To

encourage everyone, even the slower students, to attempt each problem, half of the point value of a question is awarded to those students who did not respond but have the correct answer. To win the game, the student has to balance the incentive of a quick, but possibly wrong, full-credit response with a more meticulous and carefully worked, half-credit response.

This process continues until either the time or the questions run out; usually it is the time. As an instructional activity it is important to allow time to answer questions about a math problem. To help encourage peer tutoring, the instructor may want to have the student who responded with the correct answer first explain how he arrived at the answer. The student with the highest total wins.

Conclusion

In another context, B.F. Skinner (1983, p. 26) was speaking of the desirability of computers in assisting instruction. When asked if computers could help students achieve understanding of a significant nature he replied, "Absolutely. A good (computer) program can interest students in almost anything. An algebra program can be as motivating as Pac-Man if the student is successful with it."

We agree with Skinner's assessment of the potential for educational gaming and simulations. What is needed at the present time is experimental research that will help generate evidence to demonstrate that educational gaming is effective in the instruction of advanced mathematics such as algebra,

geometry, and trigonometry. It seems certain that better teaching of mathematics through the use of educational simulations will have serious potential to improve both the attitude of students toward mathematics and student's actual achievement.

MATHARDY

	Addition and Subtraction	Multiplication and Division	Fractions	Combinations	Potluck	
10	2 - 5 + 8 - 16	23 x 47	$\frac{1}{5} - \frac{4}{3}$	2.4 + 3.56	$2^3 - 4 + 13$	10
20	26 + 116 - 48	208 ÷ 4	$\frac{2}{5} - \frac{1}{3} + 4$	12.4 x 8.23	$\frac{1}{5 - 1} - \frac{1}{5}$	20
30	14 - 8 - 114	(13 x 4) ÷ (18 x 2)	$2\frac{4}{5} \times \frac{5}{8}$	4.5 x 2 - 3.6	$\frac{-\frac{1}{5}}{7}$	30
40	24 - 7 + 13 -45 + 62	$\frac{24 \times 28}{37}$	$\frac{2}{3} - \frac{5}{6}$	123 - 6.35	(18 - 6) x 4 17 + 5	40
50	205 - (12 + 9) + 44 - 18	12 x 2 / 5	$2\frac{2}{3} \times \frac{4}{7}$	56.7 - 17.67 x 5.6 + 1.43	$2^5 - 3^2$	50

Figure 1

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THE FIVE BIG LIES OF MATH TEACHING

For those who do not remember what a "Big Lie" is, a "Big Lie" is an untruth that is told so often that people believe it in spite of the evidence.

BIG LIE # 1: Math teaching problem solving. Math problem solving is the same as real problem solving.

> Not true. The proponents of this position are under a professional obligation to provide evidence to support this contention.

BIG LIE #2: Learning math teaching mental discipline that will transfer to other forms of learning.

> Not true. The Mental Discipline lie has been repudiated for at least 100 years. The proponents of this position are under a professional obligation to provide evidence to support this contention.

BIG LIE #3: Math is used all the time by normal people in everyday life.

> Not true. Math is practically never used by any normal person outside of the specific requirements of a trade (like carpentry) or a profession (like navigation).

BIG LIKE #4: Studying math builds "character."

> Says who? The proponents of this idea are under a professional obligation to provide scientific support for such a belief.

BIG LIKE #5: Real students should like math because of the four aforementioned reasons.

> Baloney. Math is, however, used to sort students, as in the tracking that goes on in public schools or entry into two or four years schools.

The Correlates of the Big Lies of Math Teaching

Correlate A: Math teachers look at their classes for anecdotal support of the Big Five. This observation constitutes evidence.

Not true. What math teachers can observe from their classes is opinion, not evidence in the scientific sense.

Correlate B: Math learning benefits all.

Not true. Math may certainly benefit those students with specific aptitudes or interests in math, but the rest of the world shouldn't be subject to such an obligation.

Math is like liver and cooked spinich. Practically nobody likes it, but there seems to be a popular unwillingness to tell the truth about these things.

Requiring math to be taught(above the basic calculation skills which are necessary for functioning in everyday life)is like saying, "A few teachers like cooked liver and spinich. These teachers say that cooked liver and spinich is good for us and will help us solve problems in real life. Because these math teachers say spinich is good for a few all people will eat cooked spinich and liver for twelve years one period a day and the "real" students will like it."

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Rev. 12.27.88
MASH: MATH ANXIETY SCALE AND HISTOGRAM Name______________________________

Directions: Respond to each of the following statements. Mark a five (5) if the statment is true for you or you agree with it. Mark a one (1) if the statement is not true for you or you disagree with it.

(1) I avoid math whenever possible.
Agree 5 4 3 2 1 Disagree

(2) Even though I've studied well when I take math tests I blank on the exam.
Agree 5 4 3 2 1 Disagree

(3) Numbers stay in my head easily.
Agree 5 4 3 2 1 Disagree

(4) I don't like arithmetic or math.
Agree 5 4 3 2 1 Disagree

(5) When I do math homework or study I can feel myself getting tense and irritated.
Agree 5 4 3 2 1 Disagree

(6) I was born with the Math Gene.
Agree 5 4 3 2 1 Disagree

(7) I don't balance my checkbook.
Agree 5 4 3 2 1 Disagree

(8) I experience math panic as well as math anxiety.
Agree 5 4 3 2 1 Disagree

(9) A high level of sequential organization is easy for me.
Agree 5 4 3 2 1 Disagree

(10) When I take math tests I go blank.
Agree 5 4 3 2 1 Disagree

(11) I feel irritated when math teachers make students endlessly drill and practice things they already know.
Agree 5 4 3 2 1 Disagree

(12) I am not an adult female (over 16 years of age).
Agree 5 4 3 2 1 Disagree

(13) Math is not fun.
Agree 5 4 3 2 1 Disagree

(14) I have a strong dislike for math.
Agree 5 4 3 2 1 Disagree

(15) Numbers are easy for me to remember.
Agree 5 4 3 2 1 Disagree

(16) I have not voluntarily taken a math class for a long time.
Agree 5 4 3 2 1 Disagree

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GO ON TO THE NEXT PAGE.

(17) When I do or am about to do math I frequently get stomach aches.
Agree 5 4 3 2 1 Disagree

(18) Math was easy for me when I was little.
Agree 5 4 3 2 1 Disagree

(19) When it comes to math I feel helpless even though I can technically do it.
Agree 5 4 3 2 1 Disagree

(20) When I do or am about to do math I frequently get headaches.
Agree 5 4 3 2 1 Disagree

(21) I liked math and arithmentic when I was little.
Agree 5 4 3 2 1 Disagree

(22) God made social studies. An evil spirit made math.
Agree 5 4 3 2 1 Disagree

(23) I feel panicky and uneasy when I do math.
Agree 5 4 3 2 1 Disagree

(24) I remember math concepts easily.
Agree 5 4 3 2 1 Disagree

(25) I feel that I can study math successfully only if I have a real good reason.
Agree 5 4 3 2 1 Disagree

(26) I feel panicky and uneasy when I take math classes.
Agree 5 4 3 2 1 Disagree

(27) When little, I remember being encouraged about math by my teachers or adults.
Agree 5 4 3 2 1 Disagree

STOP. SCORING INSTRUCTIONS ARE ON THE NEXT PAGE.

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MASH SCORING INSTRUCTIONS

Add your totals for the items listed below:

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1._____	2._____	3._____
4._____	5._____	6._____
7._____	8._____	9._____
10._____	11._____	12._____
13._____	14._____	15._____
16._____	17._____	18._____
19._____	20._____	21._____
22._____	23._____	24._____
25._____	26._____	27._____
Totals _____	_____	_____
TENSION TRAIT	AVOIDANCE TRAIT	NATURAL ABILITY

THE NONPERFORMANCE CONTINUUM

[1]Am = Math Anxiety BAD

[2]At = Test Anxiety TERRIBLE

[3]As = School Anxiety WORSE

Any one of these forms of anxiety/apprehension is bad enough. Some students may experience all three forms of performance apprehension. The negative affect, then, is tripled.

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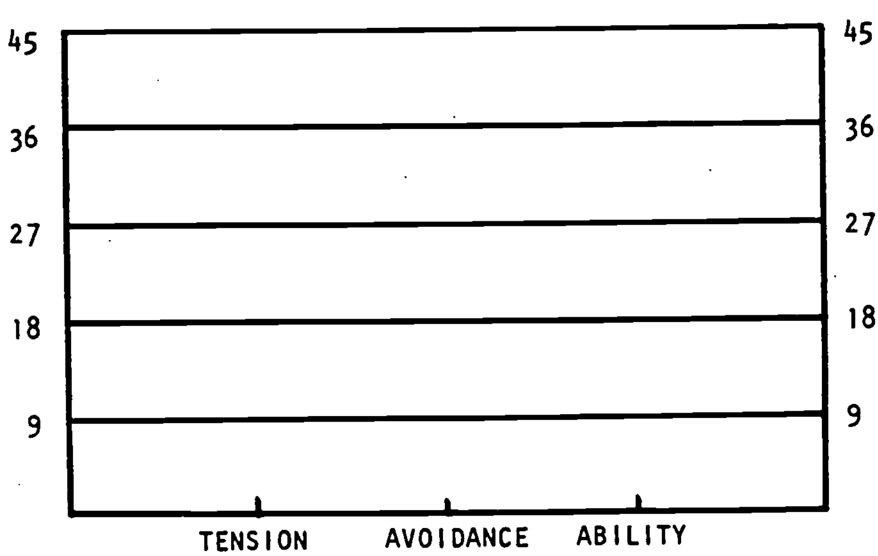
Next, plot your scores on the histogram below:



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